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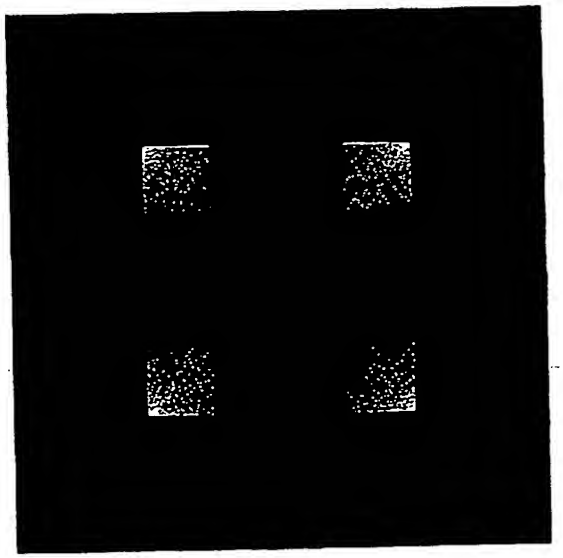
(54) Title: METHOD FOR MAKING A CODE IMAGE, ORIGINAL COMPRISING SUCH A CODE IMAGE AND PHOTOCOPIER FOR COPYING SUCH AN ORIGINAL



(57) Abstract

Method for making a code image from a picture, said code image being detectable by a photocopier with a sampling frequency. In the method, the Fourier transform of the picture is determined, all frequency components larger than half of the sampling frequency are removed from the Fourier transform, the remaining frequency components of the Fourier transform are mirrored about the axes which correspond to half of the sampling frequency, and the inverse Fourier transformation is applied hereto. An original provided with such a code image offers a security against copying up to a certain point and can be detected by a detection apparatus of a photocopier.

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Method for making a code image, original comprising such a code image and photocopier for copying such an original

The invention relates to a method for making a code image from a picture, said code image being detectable by a photocopier with a sampling frequency.

The invention also relates to an original comprising a code image detectable by a photocopier with a sampling frequency and to a photocopier with a sampling frequency for copying an original comprising a code image, the photocopier having a detection apparatus for detecting the code image.

Now that advanced photocopiers, among them in particular colour photocopiers with array laser scanning and graphic format stations, have become available to a large public, nowadays large numbers of copies of an original can be cheaply and speedily obtained, the copies being completely or almost completely indistinguishable from the original.

In order to prevent unauthorized copying of originals, such as securities, for example bank notes, or confidential documents, Dutch patent application 90.02740 discloses providing the original with a copy security element in the form of a grid angle modulated code image which is detectable by a photocopier. Although this grid angle modulated code image prevents unauthorized copying with a fair amount of success, effective operation can be negatively influenced by the use of digital filters or other image correcting techniques. The need for other security elements is thus still present.

It is among other things an object of the present invention to provide an alternative code image which is at least substantially imperceptible by the human visual system, but which can easily be detected by (in particular digital) photocopiers.

For this purpose a method of the sort named in the introductory part is characterized according to the invention in that the method comprises the following steps:

- determining the Fourier transform of the picture,
- removing all frequency components larger than half of the sampling frequency from the Fourier-transform,
- mirroring the remaining frequency components of the Fourier transform about the axes which correspond to half of the sampling frequency, and
- applying the inverse Fourier transformation hereto.

The invention is based on the insight that for the graphic reproduction of images on a substrate, for example paper, only a small part of the total information capacity of this substrate is used. The human visual system can perceive frequencies of up to approximately 50 periods per degree, which corresponds to approximately 10 periods per millimetre on the substrate at an assessment distance of 30 cm. However, present-day digital photocopiers scan an original at a higher frequency of, for example, 400 dpi or 16 periods per millimetre. This frequency band (also called sampling band) is thus outside the band width of the human visual system and can be considered to be a side band which can serve as 'carrier wave' for information which is beyond the assessment range of the human visual system. The invention makes use of this by removing almost all frequency components from the information on the picture carrier which are in the low frequency bands visible to the human eye. The remaining frequency components appear to give a digital photocopier sufficient information to reconstruct the picture and make it visible

again to the human eye.

After extensive research within the theory of signal processing there it was found that removing those frequency components from the picture which are visible to the human eye, whilst the picture can still be 'seen' by a digital photocopier can take place by means of the inventive method.

The inventive method (also called SABIC: Sample-Band Image Coding) is based, among other things, on the Sampling theorem which applies to sampling images by digital photocopiers. This theorem postulates that if an image is sampled with a frequency which is higher than twice the highest frequency which occurs in the image, that image can be reconstructed completely from the samples. If, however, the sampling frequency is too low then the so-called aliasing effect occurs. That means that for frequencies in the image which are under half of the sampling frequency, in other words the remaining frequency components, it holds that these frequencies, when sampled thus when copied, are mirrored about the axis of half the sampling frequency.

This explains why in the inventive method the frequency components above half of the sampling frequency are removed and are mirrored about the axes which correspond to half of the sampling frequency.

At the same time the invention provides an original protected against unauthorized copying comprising a code image detectable by a photocopier with a sampling frequency, which original is characterized in that the code image is formed by the inverse Fourier transform of a processed Fourier transform of a picture, the processed Fourier transform of the picture being the Fourier transform of the picture from which all frequency components

larger than half the sampling frequency have been removed and the remaining frequency components being mirrored about the axes which correspond to half of the sampling frequency.

Such a code image applied to the original is not visible to the human eye but appears on the copy after the copying process. By so doing the copy is distinguishable from the original.

As an original image with a code image obtained by the invention and overlayed thereon can be separated by means of digital high-pass and low-pass filters, a photocopier should preferably be provided with a detection apparatus for detecting the inventive code image in order to prevent unauthorized copying. When the detection apparatus recognizes a code image in the original, then, preferably by means of an inhibition circuit, copying is made impossible. Thus a digital photocopier can be produced in such a way that originals with an inventive code image cannot be copied.

Some embodiments of the invention will hereinafter be described in more detail with reference to the drawing. In the drawings

Fig. 1 shows a picture which is to be made into a code image,

Fig. 2 shows the amplitude of the Fourier transform of figure 1,

Fig. 3 shows the phase of the Fourier transform of figure 1,

Fig. 4 shows the amplitude according to figure 2 after the inventive process,

Fig. 5 shows the phase according to figure 3 after the inventive process,

Fig. 6 shows the inverse Fourier transform, the code image, of figures 4 and 5,

Fig. 7 shows a copy of figure 6 by means of a digital photocopier,
Fig. 8 shows an original,
Fig. 9 shows the original of figure 8 with the code image of figure 6 superimposed thereon,
Fig. 10 shows a copy of figure 9 by means of a digital photocopier,
Fig. 11 shows the picture of figure 9 after processing by a low-pass filter,
Fig. 12 shows the picture of figure 9 after processing by a high-pass filter,
Fig. 13 shows a copy of figure 12 by means of a digital photocopier.

In order to let the description be as clear as possible, all the pictures represented in the figures have been represented about five times the full size. Apart from that all figures have been executed with a resolution of 512 x 512 picture elements, which in general deviates from the resolution used in practice.

In figure 1 an arbitrary picture is shown which is to be converted by means of the method according to the invention into a code image detectable by a photocopier with a sampling frequency. In this embodiment the Fourier transform of this picture is determined as follows. The picture is discreted by determining the grey values of each picture element. This determination of the grey values can be done by measuring light reflected by the picture element. Thus a two dimensional function of grey values is obtained, which is subjected to a discrete two dimensional Fourier transformation, for example a Fast Fourier Transform algorithm. The amplitude of the Fourier transform of the picture and the phase thereof are shown in figures 2 and 3 respectively. Then the frequencies which are larger than half of the sampling frequency are filtered out of this amplitude and phase, and the frequencies which are

smaller than half of the sampling frequency are mirrored about axes which correspond to half the sampling frequency. The resulting processed amplitude and phase Fourier transforms are shown in figures 4 and 5 respectively.

The inverse Fourier transform, which is shown in figure 6, and which forms the code image is then determined from these two pictures. In this code image all information which was also visible to the human eye, that is which was in a low frequency band, is transferred to a high frequency band and because of this is then no longer visually perceptible. Sufficient information remains, however, for a digital photocopier to reconstruct the picture. This is shown in figure 7. Figure 7 shows the code image of figure 6 which has been sampled, that is copied, with the correct frequency and phase (in this example with a resolution of 128 x 128 picture elements).

As the sampling frequency of the photocopier is not larger than twice the highest frequency in the code image, with frequencies between a half and a whole sampling frequency, an under-sampling occurs. As a result of this under-sampling a new mirroring of the frequencies about axes with half the sampling frequencies occurs, as a result of which the frequencies come into a lower frequency band and are thus visible to the human eye.

In order to secure an original against unauthorized copying, as is shown for example in figure 8, this original is provided preferably over the whole surface with a code image as shown in figure 6. Figure 9 shows the original with the superimposed code image. If a copy is made of that original with code image (figure 10) then the picture reappears, as a result of which the copy becomes useless.

Although this offers a security up to a certain point, the

the two superimposed pictures can be separated from one another by means of proper use of digital low-pass and high-pass filters which are a standard feature in digital photocopiers, by which means unauthorized copying could still be possible. Figure 11 thus shows the result after using a digital low-pass filter and figure 12 the result after using a high-pass filter. The sampling, that is the copying, of the code image of figure 12 with the correct frequency allows the original picture to return. By providing photocopiers according to the invention with a detection apparatus for detecting a code image, it is possible to take certain measures when a code image is detected. Thus the detection apparatus preferably contains an inhibition circuit, which inhibits every copying activity when detecting a code image. Alternatively, in the case of positive detection deformations can be introduced in the copy or a quiet alarm can be sounded.

AS/FL

C L A I M S

1. Method for making a code image from a picture, said code image being detectable by a photocopier with a sampling frequency, **characterized in that** the method comprises the following steps:

- determining the Fourier transform of the picture,
- removing all frequency components larger than half of the sampling frequency from the Fourier transform,
- mirroring the remaining frequency components of the Fourier transform about the axes which correspond to half of the sampling frequency, and
- applying the inverse Fourier transformation hereto.

2. Original comprising a code image detectable by a photocopier with a sampling frequency, **characterized in that** the code image is formed by the inverse Fourier transform of a processed Fourier transform of a picture, the processed Fourier transform of the picture being the Fourier transform of the picture from which all frequency components larger than half the sampling frequency have been removed and the remaining frequency components being mirrored about the axes which correspond to half of the sampling frequency.

3. Photocopier with a sampling frequency for copying an original comprising a code image, the photocopier having a detection apparatus for detecting the code image, **characterized in that** the detection apparatus is suitable for detecting a code image which is formed by the inverse Fourier transform of a processed Fourier transform of a picture, the processed Fourier transform of the picture being that Fourier transform of the picture from which all frequency components larger than half of the sampling

frequency have been removed and the remaining frequency components being mirrored about the axes which correspond to half of the sampling frequency.

4. Photocopier according to claim 3, **characterized in that** the detection apparatus contains an inhibition circuit.

FIG. 1

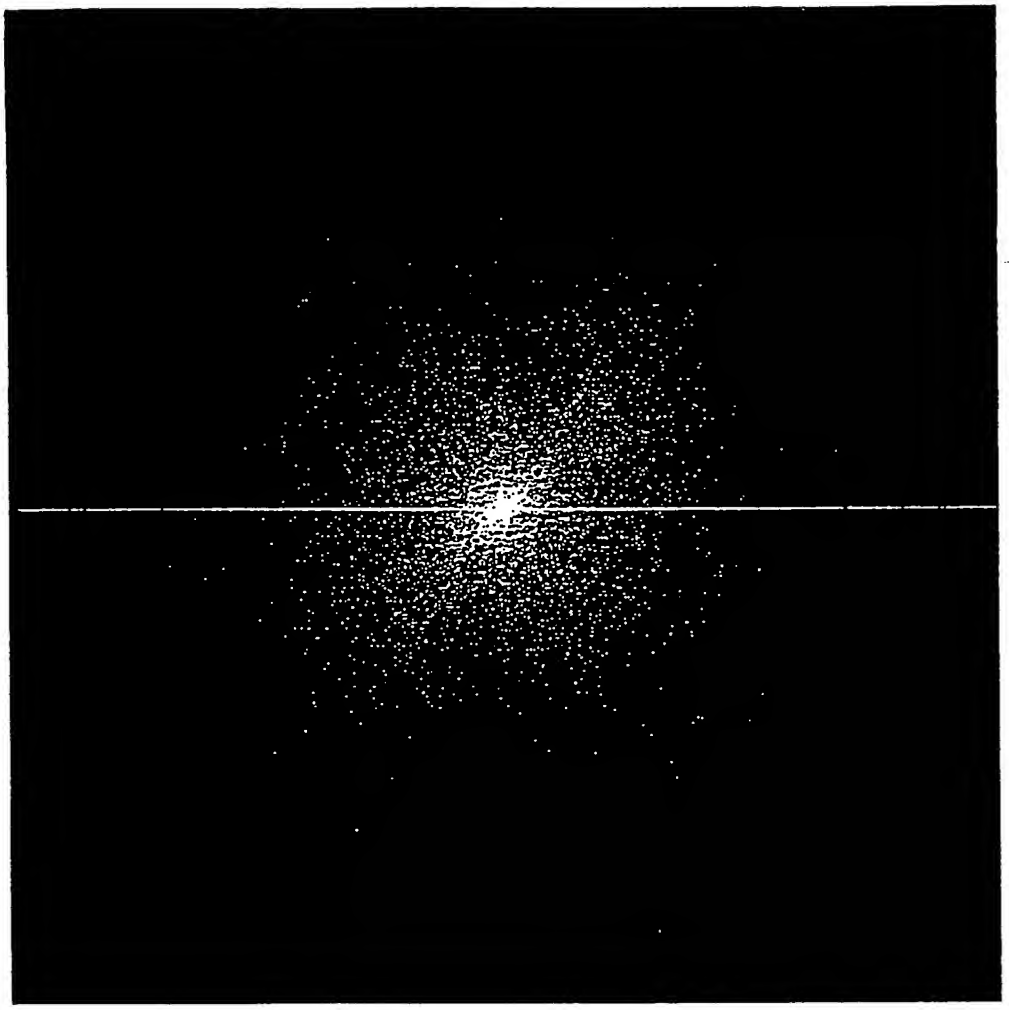

FIG. 2

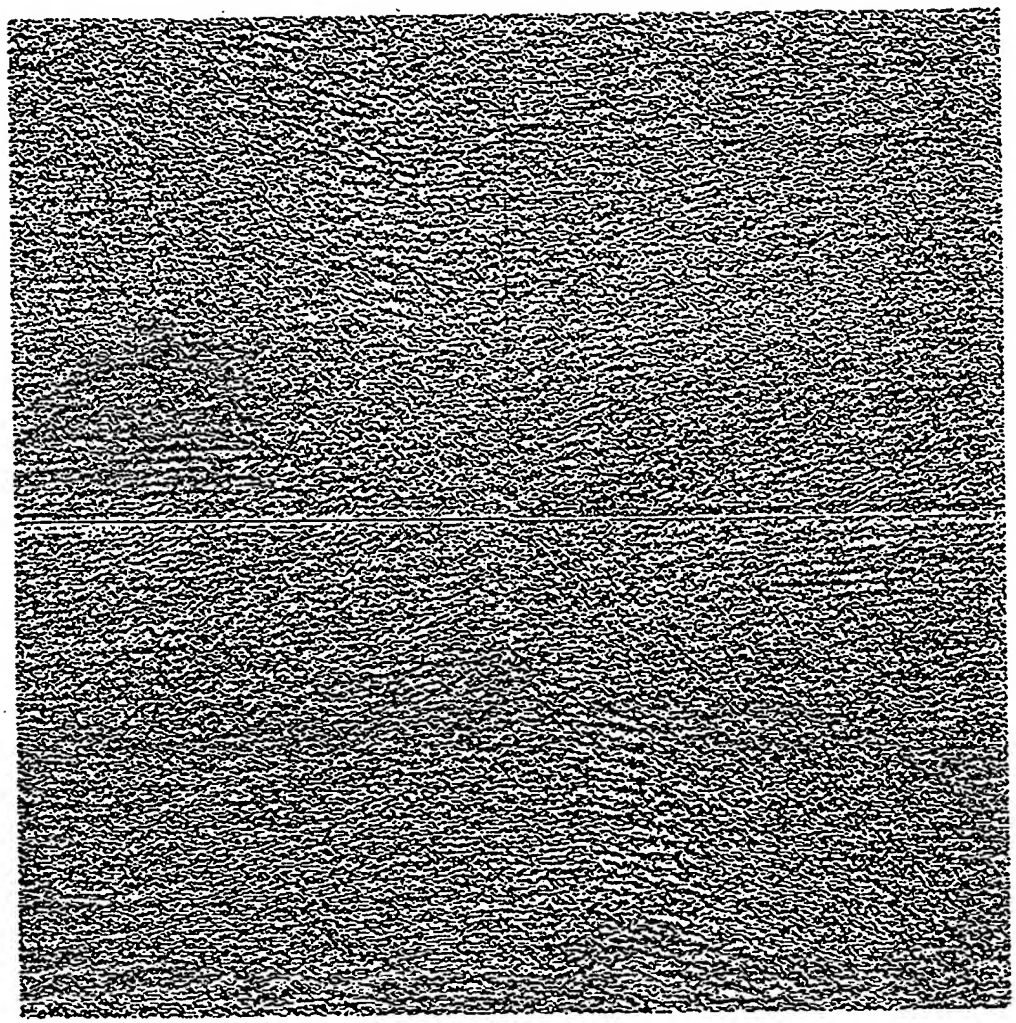

FIG. 3

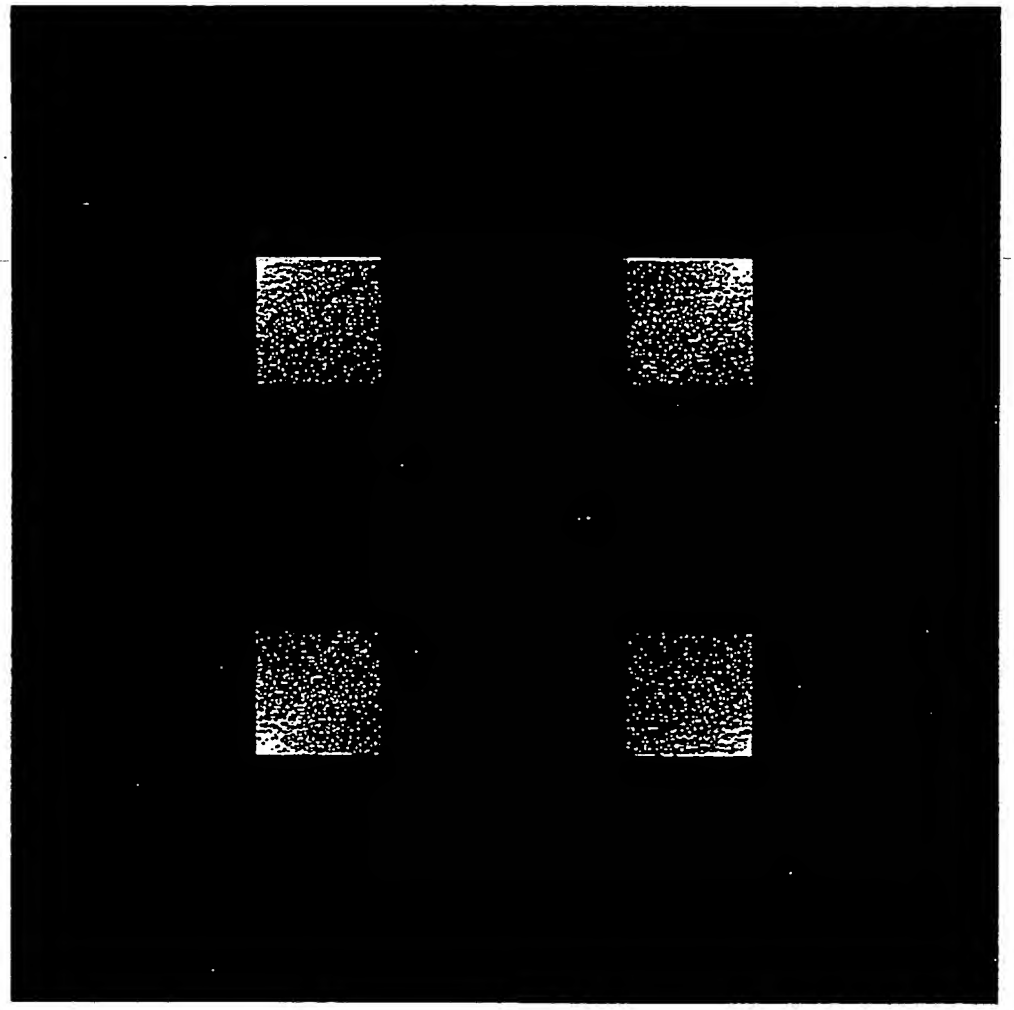

FIG. 4

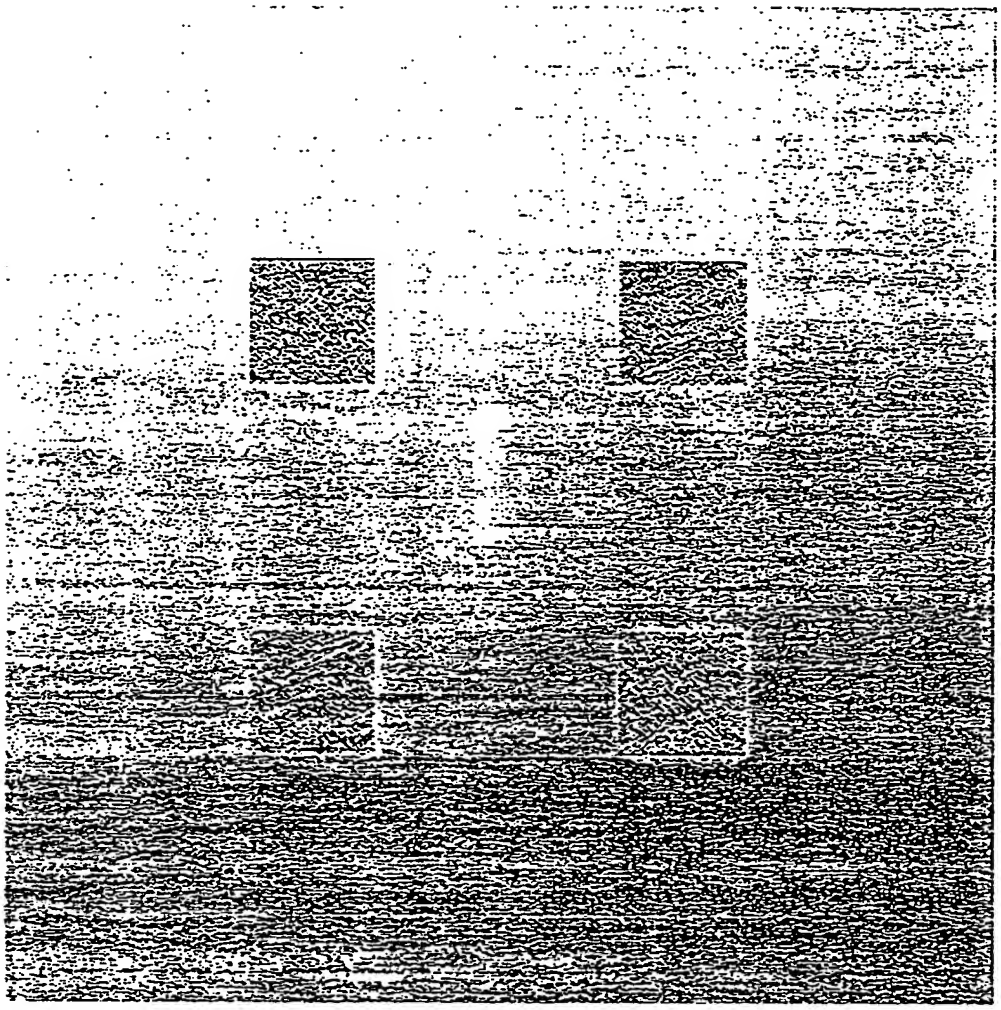

FIG. 5

FIG. 6

FIG. 7

FIG. 8

FIG. 9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

INTERNATIONAL SEARCH REPORT

Intern nal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B44F1/12 H04N1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N B42D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,93 25038 (ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE) 9 December 1993 see the whole document	1-3
A	EP,A,0 382 549 (CANON KABUSHIKI KAISHA) 16 August 1990 see page 2, line 12 - line 20 see page 2, line 36 - page 3, line 4	4
A	EP,A,0 490 457 (JOH. ENSCHEDÉ EN ZONEN GRAFISCHE INRICHTING B.V.) 17 June 1992 see abstract see page 3, line 11 - line 14 & NL,A,9 002 740 cited in the application	4
A	GB,A,2 217 258 (SUOMEN PANKIN SETELIPAINO) 25 October 1989	

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Date of the actual completion of the international search	Date of mailing of the international search report
20 October 1994	31.10.94

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	NL,A,9 201 701 (JOH. ENSCHEDÉ EN ZONEN GRAFISCHE INRICHTING B.V.) 2 May 1994 see the whole document	1-4

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nformation on patent family members

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